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NOTES ON SOME KANSAS PAVING BRICK.

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Read before the Academy, at Topeka, December 30, 1904.

FOR the last four or five years, the writer has done considerable work in the University testing laboratories on Kansas paving brick from several plants, and, for the sake of comparison, on a few brands of established reputation from other states. The results of this work, in part, have been grouped and studied, and are presented in the tables and diagrams incorporated in this paper.

Good paving brick must be sound, homogeneous, little subject to weather action, strong enough to bear the loads that come upon them, tough enough not to chip or fracture under impact, and hard and cohesive enough to resist the abusive effect of traffic.

The tests that have been generally used are four: (1) Absorption; (2) crushing strength; (3) transverse strength; (4) the rattler test. Of these, the first is no longer used. It has been quite well established that any brick, whether porous or close grained, which will meet the requirements of the other tests, will have strength enough to withstand the action of freezing. It has also been found, through investigation on a large scale, by committees of the National Brick Manufacturers' Association, that the crucial test is the last named; and, also, that the tests for crushing and transverse strength are valuable through furnishing some knowledge of internal structure of brick.

The results of transverse tests are given in table I, and of crushing tests in table II. The Neodesha brick were samples made in Ohio from Neodesha shale, before any brick plant was located at this place, and are to be taken only as an indication of what the shale-bed might yield.

Back of the tests on Leavenworth brick lies a story of some months of experimentation in trying to improve the quality of the output and to meet a certain specification as to transverse strength required by the city engineer of Leavenworth.

The clay-bank at Leavenworth is one that is fat; that is, having too much alumina and too little silica. The brick made from it are too brittle and possess a bad structure. The auger machine that drives the clay through the dies gave a rotary motion to the clay stream, resulting in an internal series of concentric layers, which would separate to some degree during the burning process. The modification of

machinery and dies and the mixture of sand with the clay to reduce its richness finally overcame the difficulty of structure and met the specified requirement as to transverse strength.

Transverse tests were made by placing the brick edgewise on knife edges, six inches apart, with the load applied at the center of top edge through a third knife edge. Crushing tests were made on half brick broken in the transverse tests, these being bedded edgewise in plaster of Paris on both the top and bottom. The specimen was placed in the machine, an Olsen of 100,000 pounds capacity, before the plaster was set; then under a light load of one to two thousand pounds it was allowed to rest for about ten minutes; then power was applied slowly till failure resulted. A few brick have been broken with strawboard or with soft pine cushions. Though more rapid, preference is given to the plaster bedding.

The rattler test is designed to furnish evidence of the ability of brick to withstand impact and abrasion—the blows from horses' feet that will chip off edges and corners and the wear from both horses and vehicles. The standard rattler is a cast-iron barrel with fourteen-sided polygons for ends and fourteen staves, set with small cracks between them. It is twenty inches long and twenty-eight inches in diameter, and is rotated with its axis horizontal at from twenty-seven to thirty-two revolutions per minute. Under the old method, enough brick to equal fifteen per cent. of the volume of the rattler, somewhere from twenty-two to twenty-six brick of common sizes, constituted the sole charge, and these were tumbled around for a maximum of 1800 revolutions.

Table III and figure 1 give the results of tests made by this method. Behind the Lawrence records there also is a story of many months' experimentation in modifying machinery, in mixing materials for different parts of the clay-bank, and in regulating the process of drying and burning. No. 39 was the first brick to come within the requirements set by the specifications for the first street paving in Lawrence. Tests of later brick are better still. Every manufacturer of paving brick has his own problem in adapting his methods to his materials. Clay-banks are not alike, and what will work in one place will not in another. Moreover, as the character of a shale-bed or clay-bank may change in a few feet of distance, the brickmaker must keep vigil if he is to maintain a high and uniform standard.

A rattler test, when platted as in figure 5, is significant in several ways. A curve that rises rapidly during the first 200 or 400 revolutions indicates a large loss due to the chipping off of edges and corners. This means brittleness. A flat curve here means relative greater toughness. If a curve continues to rise rapidly and the total loss is

high, this is evidence that loss by abrasion chiefly has occurred. The flatter the curve, as a whole, the better will the brick wear in the street. Tests of brick giving high curves are invariably very dusty after 400 revolutions. A smooth curve indicates a brick of quite uniform structure and texture; an irregular one, like some shown in figure 8, for example, indicates some structural defect. In the case cited, the trouble was largely due to a curve and some separation of the concentric layers.

The method which puts brick only in the rattler has been abandoned for the shot method—partly because it was too severe, giving high percentage losses, and partly because it gave too much importance relatively to the impact side of the test. The present practice puts into the rattler twelve brick with 225 pounds of cast-iron cubes, one and one-half inches on each edge, and seventy-five pounds of larger cast-iron blocks, two and one-half by two and one-half by four and one-half inches. The results of tests by the shot method are shown in table IV and figure 6, and these will be self-explanatory.

In figure 7 are shown the results of tests made to determine the effect of water on the brick on the rattler losses. The Topeka and Galesburg brick absorbed but small quantities of water. For the Pittsburg, the wet weight of the soaked lot was about one pound in excess of dry weight. The Coffeyville, a gas-burned brick, and therefore more porous, had absorbed about a total of two pounds. During testing, dust began flying at 200 to 400 revolutions for the first two named, at 800 for Pittsburg, and 1100 for Coffeyville. The significant thing here is, that all brick should be rattled dry, if the results are to be compared.

In figure 8, the curves for Buffalo brick show in a marked way the effects of overburning—a loss of toughness and increased brittleness. The curves for Lawrence were chosen because they illustrate irregularities due to imperfect structure, and at the same time the effects of underburning—softness and little resistance to abrasion. These lines are not to be taken as characteristic of Lawrence brick, which now rank well and among the best made in the state.

In all of the tables, like laboratory numbers refer to the same lot of brick and received at the laboratory at the same time.

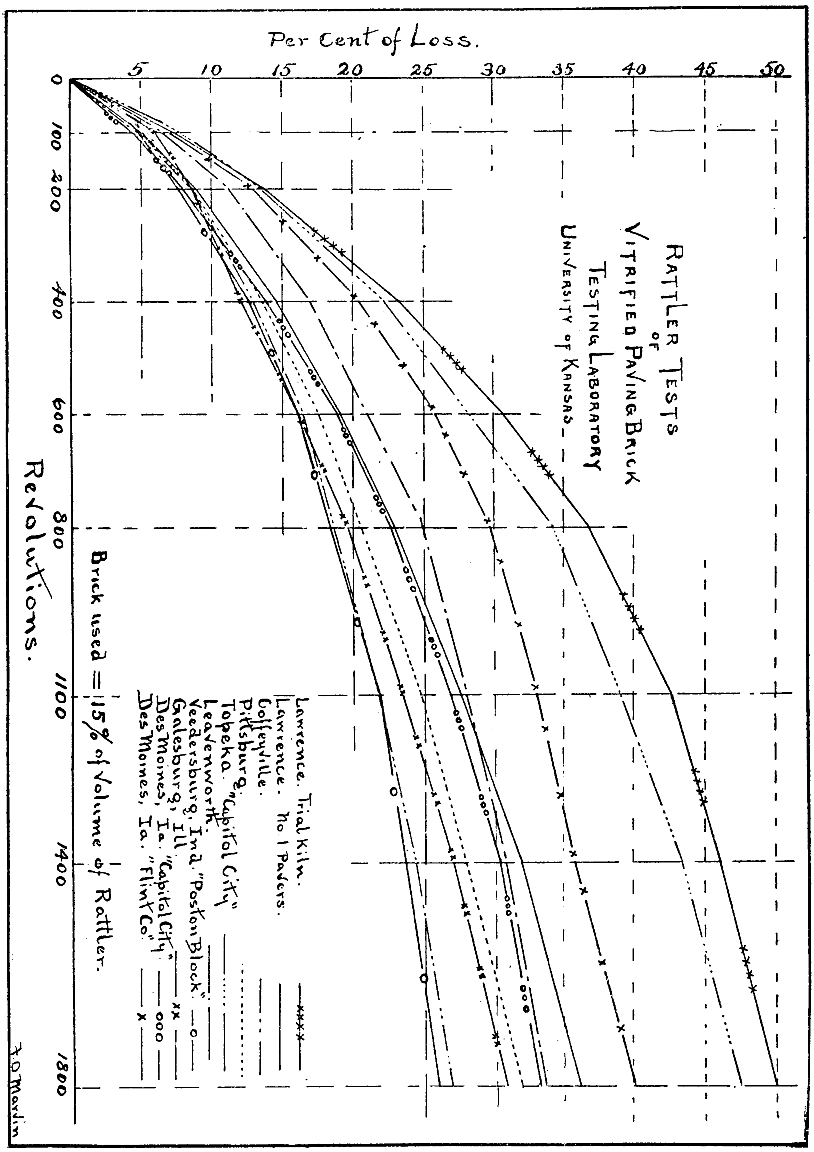

FIG. 5. Diagram of rattler tests on brick.

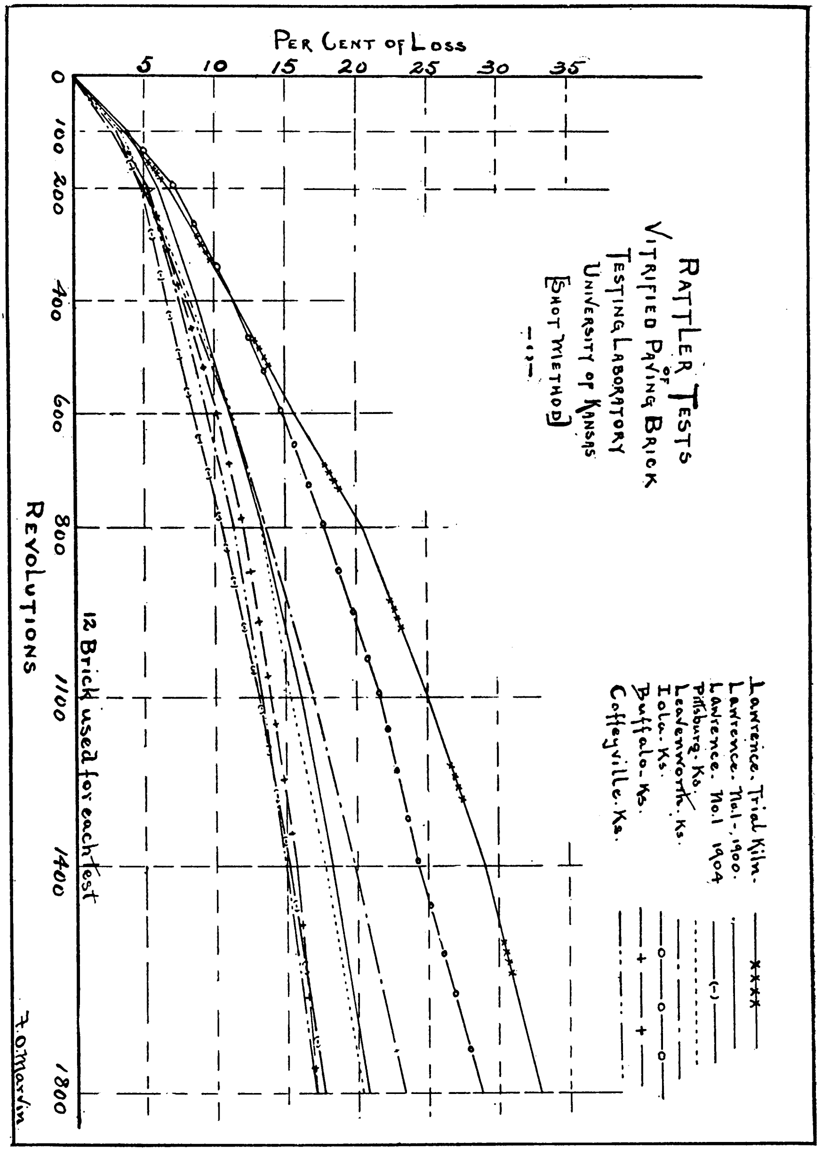

FIG. 6. Diagram of rattler tests on brick.

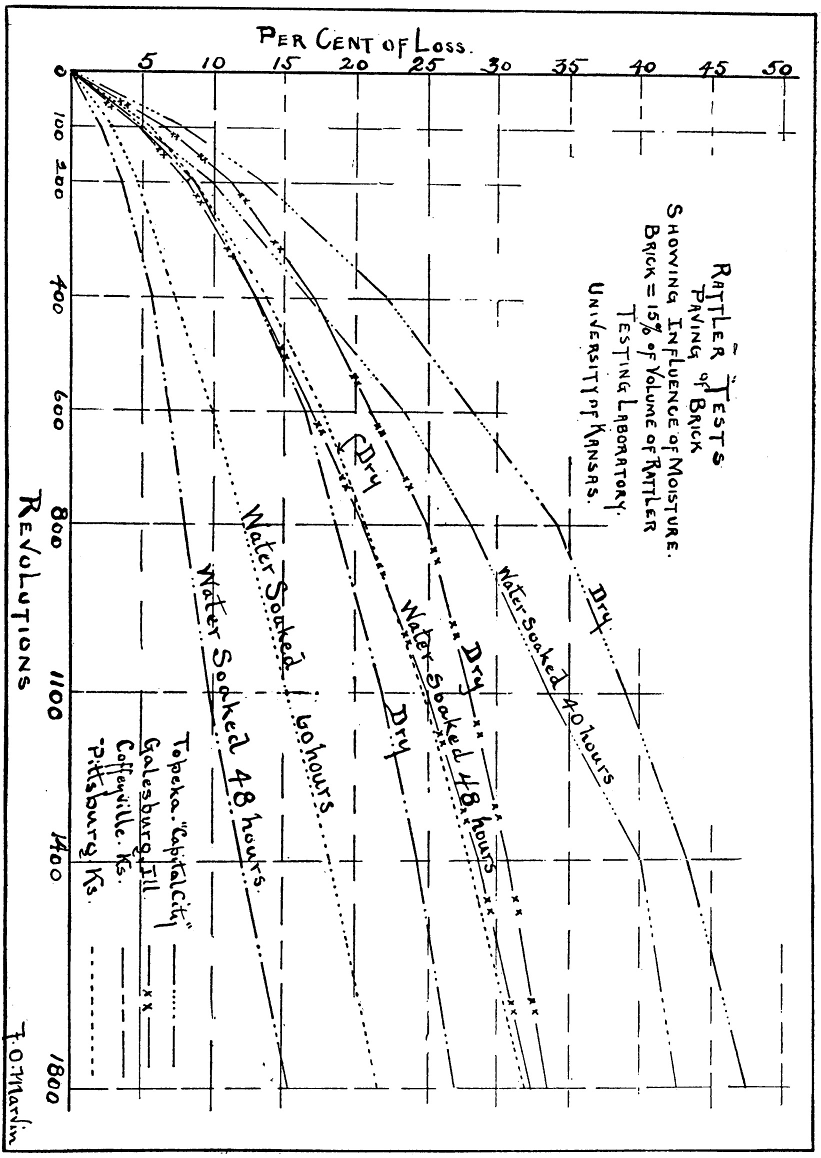

Fig. 7. Diagram of rattler tests on brick, showing effect of moisture on strength of brick.

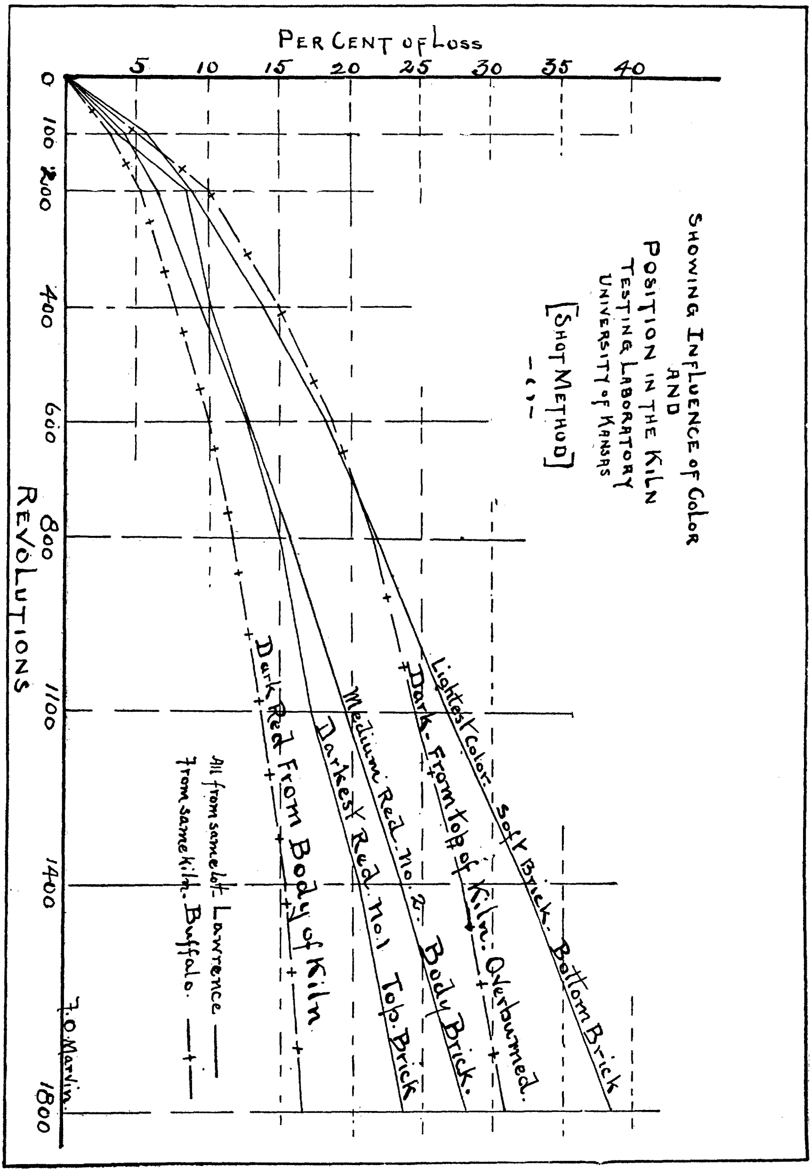

FIG. 8. Diagram of rattler tests on bricks, showing influence of color and position in kiln on strength of brick.

TABLE I.—Transverse tests of Kansas vitrified paving brick; testing laboratory, University of Kansas.

Lab. No.	Location and brand.	No. tested.	Average size of cross-section.	Average load at rupture.	Modulus of rupture $\frac{3wl}{26d^2}$
26	Lawrence, first kiln	12	2.39 x 3.83	12,516	3,220
27	" second kiln	12	2.38 x 3.81	8,128	2,106
9	Coffeyville, May, '97	4	2.28 x 4.07	9,244	2,201
10	" January, '00	10	2.28 x 4.07	11,185	2,649
7	Pittsburg	5	2.38 x 3.79	8,974	2,360
8	"	6	2.45 x 3.72	10,153	2,696
19	Topeka, "Capital City"	4	2.32 x 3.70	8,450	2,684
20	" "	12	2.20 x 3.63	8,069	2,680
21	" No. 2	4	2.34 x 3.88	6,802	1,749
11A	Leavenworth	6	2.56 x 3.72	9,432	2,207
11B	" "O," pure shale	5	2.70 x 4.17	10,032	1,928
12	" shale and river sand	5	2.72 x 4.10	10,919	2,143
13	" " "	9	2.52 x 3.86	10,677	2,548
14	" soft burned	4	2.69 x 3.99	7,890	1,656
15	" hard burned	6	2.48 x 3.67	8,940	2,409
16	" fine grained	6	2.51 x 3.77	9,253	2,324
17	" coarse grained	6	2.48 x 3.69	9,165	2,443
18	" beveled edges	11	2.43 x 3.55	7,590	2,331
22	Osage City, No. 1, May, '97	4	2.12 x 3.54	8,100	2,715
23	" No. 2, May, '97	4	2.15 x 3.61	4,692	1,567
24	" No. 3, May, '97	2	2.30 x 3.87	3,820	1,002
25	Atchison, May, '97	4	2.24 x 3.81	7,950	2,179
29	Iola, light color	6	2.36 x 3.83	6,220	1,633
30	" dark red	7	2.36 x 3.70	7,900	2,233
28	Neodesha	3	2.38 x 3.82	7,747	2,007
6	Galesburg, Ill	9	2.57 x 3.82	9,600	2,311
1	Des Moines, Iowa, "Capital City"	5	2.50 x 3.75	13,700	3,525
2	" " "	6	2.56 x 3.76	12,334	3,139
3	" " "T"	5	2.45 x 3.90	12,001	2,929
4	" " "Flint Co."	5	2.54 x 3.83	10,702	2,686
5	" " "Iowa"	6	2.60 x 3.94	13,580	3,038

TABLE II.—Crushing tests of Kansas vitrified paving brick; testing laboratory, University of Kansas. [Half-brick used.]

Lab. No.	Location and brand.	Number tested.	Average load at crushing.	Crushing load per sq. inch.
26	Lawrence, first kiln	10	87,537	9,550
27	" second kiln	9	51,457	5,759
9	Coffeyville	4	79,732	8,466
10	"	10	97,429	11,040
7	Pittsburg	5	94,746	10,447
8	"	6	95,722	10,082
19	Topeka, "Capital City," No. 1	4	95,080	11,464
21	" " No. 2	4	69,680	8,078
11 A	Leavenworth	6	57,562	5,736
11 B	" "O," pure shale	5	87,046	7,806
12	" shale and river sand	5	62,846	6,118
13	" " "	10	67,548	6,978
14	" soft burned	4	79,680	7,637
15	" hard burned	6	71,203	7,270
16	" fine grained	6	73,680	7,562
17	" coarse grained	6	50,000	5,151
18	" beveled edges	12	36,356	4,009
22	Osage City, No. 1	4	53,902	6,879
23	" No. 2	4	33,077	4,251
25	Atchison	4	59,340	6,852
20	Topeka, No. 1	12	49,503	6,273
29	Iola, light color	5	51,349	5,997
30	" dark red	5	59,148	6,790
28	Neodesha	3	36,472	4,832
6	Galesburg, Ill	10	90,640	9,516
1	Des Moines, "Capital City"	4	72,294	7,147
2	" "	5	60,392	6,959
3	" "T"	5	70,986	7,390
4	" "Flint Co."	4	74,442	7,783
5	" "Iowa"	5	58,446	5,607

TABLE III.—Rattler tests of Kansas vitrified paving brick; testing laboratory, University of Kansas. Tests by 15 per cent. volume method. Averages of two tests.

Lab. No....	Location and brand.	Date.	Number of brick to test.	Revolutions per minute.	Per cent of loss at end of certain revolutions.							
					100	200	400	600	800	1,100	1,400	1,800
26	Lawrence, 1st kiln...	Dec. '99	24	28	6.0	10.8	17.5	22.1	26.2	31.4	35.7	39.8
27	Lawrence, 2d kiln...	Dec. '99	24	28	10.8	16.7	25.5	31.1	35.2	40.0	43.6	47.8
31	Lawrence............	Jan. '00	23	28	7.0	12.2	20.0	26.0	30.4	35.6	39.1	43.4
32	Lawrence............	Jan. '00	24	27.5	8.8	15.3	25.6	32.5	36.2	43.4	47.1	50.4
33	Lawrence, top of kiln, hardest.......	Feb. '00	26	28	5.5	9.4	18.5	24.8	29.5	36.7	41.8	47.3
34	Lawrence, body of kiln	Feb. '00	26	27	7.0	11.6	20.1	25.8	31.2	36.3	41.5	45.4
35	Lawrence, bottom of kiln, softest........	Feb. '00	24	28	7.6	13.8	23.4	30.7	36.7	42.6	45.9	50.7
36	Lawrence............	Mar. '00	23	29	5.9	10.3	16.9	21.3	26.7	32.1	36.3	40.0
37	Lawrence............	Mar. '00	25	28	6.6	12.5	21.2	26.8	30.8	35.4	39.5	43.2
38	Lawrence............	Mar. '00	22	28	5.8	10.2	16.9	22.6	27.9	33.9	38.8	45.1
39	Lawrence, single stream	May '00	24	27.5	5.2	9.0	14.7	19.2	23.0	27.7	31.8	36.1
10	Coffeyville...........	Jan. '00	23	28	5.5	8.6	13.6	17.6	20.2	23.5	27.0	29.0
10	Coffeyville...........	Jan. '00	23	28	4.9	8.6	13.0	16.5	18.6	21.8	24.3	27.0
10	Coffeyville, water-soaked 48 hours ...	July '00	23	27	2.1	3.6	5.7	6.9	8.0	9.6	12.0	15.3
8	Pittsburg............	Jan. '00	25	28	5.1	8.6	13.7	17.6	20.6	24.8	27.9	31.9
8	Pittsburg, water-soaked 60 hours....	July '00	25	29	2.6	4.7	7.2	9.9	12.1	15.2	18.2	21.5
19	Topeka, "Capital City".	Jan. '00	29	28	7.9	13.6	22.2	28.2	34.2	39.0	43.3	47.4
19	Topeka, water-soaked 40 hours....	July '00	29	29	5.1	10.0	16.7	23.4	28.0	33.6	40.1	42.7
15	Leavenworth	Jan. '00	23	28	4.6	7.9	13.2	17.7	21.2	25.1	29.5	34.7
17	Leavenworth	Jan. '00	22	28	5.6	9.6	15.2	19.1	22.1	26.4	30.6	33.7
18	Leavenworth, beveled edges..........	July '00	27	26	6.0	8.8	12.1	16.2	19.7	23.5	27.0	30.8
40	Veedersburg, Ind., "Poston block"...	July '00	14	28	5.0	7.7	12.6	16.1	18.5	21.9	23.7	26.0
6	Galesburg, Ill., Purington Co.........	Feb. '00	24	28	6.6	11.3	17.0	21.0	24.9	28.0	30.7	33.5
6	Galesburg, water-soaked 48 hours....	July '00	24	28	4.8	8.2	12.9	16.8	20.5	25.0	28.7	32.4
1	Des Moines, Iowa, "Capital City"....	Jan. '00	22	28	4.7	8.2	14.0	19.0	22.8	26.8	30.3	33.2
4	Des Moines, "Flint Co."	Jan. '00	23	28	7.2	13.1	20.4	25.9	29.6	33.0	35.6	39.9
5	Des Moines, "Iowa" and "Flint," mixed,	Jan. '00	21	28	5.5	9.5	15.5	20.1	24.1	28.2	31.5	34.9

TABLE IV.—Rattler tests of Kansas vitrified paving brick; testing laboratory, University of Kansas. Shot tests. Averages of two tests of twelve brick each.

Lab. No......	Location and brand.	Date.	Number of brick tested..	Revolutions per minute..	Per cent. of loss at end of certain revolntions.							
					100	200	400	600	800	1,100	1,400	1,800
8	Pittsburg	July '00	12	28.0	3.3	5.8	9.3	11.8	13.8	16.5	19.2	21.8
45	Pittsburg	Oct. '01	12	28.5	3.4	5.2	8.2	11.1	13.1	15.2	17.6	20.2
26	Lawrence	July '00	12	26.0	3.7	6.6	11.3	15.6	20.3	24.9	28.9	32.9
39	Lawrence, No. 1....	July '00	12	27.5	3.9	6.0	8.7	11.0	13.3	16.0	18.1	20.7
42	Lawrence, soft No. 2,	Dec. '00	12	27.0	5.7	9.0	14.0	18.3	22.0	27.0	32.7	39.0
43	Lawrence, medium No. 2..	Dec. '00	12	27.5	3.6	8.6	10.2	12.9	15.8	19.8	23.8	28.8
41	Lawrence, No. 1....	Dec. '00	12	28.0	4.1	6.5	9.7	12.8	15.1	17.4	20.9	24.3
49	Lawrence, No. 1....	Aug. '04	12	30.0	......	4.2	6.6	8.5	10.4	13.0	15.1	17.5
30	Iola................	Nov. '00	12	27.5	3.8	7.2	11.3	14.7	17.6	21.5	24.2	28.6
48	Iola, Union Co.....	June '04	12	31.0	4.8	8.2	13.9	17.9	21.4	25.8	27.8	30.8
46	Buffalo............	April '04	12	30.5	3.9	6.0	9.4	11.5	12.8	14.7	17.1	18.5
50	Buffalo, top of kiln...	Nov. '04	12	31.0	5.0	10.1	15.1	18.9	21.8	24.8	28.2	31.4
51	Buffalo, body of kiln..	Nov. '04	12	30.5	3.1	5.3	7.8	10.1	11.9	13.8	15.6	17.0
44	Leavenworth.......	Oct. '02	12	28.5	2.8	5.0	8.0	11.0	13.5	16.8	19.7	23.2
10	Coffeyville.........	April '02	12	27.5	3.1	5.0	7.6	9.4	11.2	13.1	14.9	17.0